UNIVERSITY OF JOHANNESBURG

# FACULTY OF SCIENCE

## DEPARTMENT OF APPLIED PHYSICS & ENGINEERING MATHEMATICS
NATIONAL DIPLOMA IN CHEMICAL ENGINEERING

**MODULE** PHY1BCT
ENGINEERING PHYSICS II

**CAMPUS** **DFC**

## NOVEMBER EXAMINATION

**DATE: 06 November 2014** **SESSION: 12:30 – 15:30**

**ASSESSOR** **Mr. T.G. Mathe**

**INTERNAL MODERATOR** **Dr. L. Reddy**

**DURATION 3 HOURS** **MARKS 140**

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**NUMBER OF PAGES: 8 PAGES, INCLUDING 2 ANNEXURE (DATA SHEET).**

**INSTRUCTIONS:**
- **ANSWER ALL THE QUESTIONS.**
- **KEEP ALL SUB-QUESTIONS TOGETHER.**
- **CALCULATORS ARE PERMITTED (ONLY ONE PER STUDENT).**
- **START EACH QUESTION ON A NEW PAGE.**
- **NUMERICAL ANSWERS ARE TO BE EXPRESSED IN SCIENTIFIC NOTATION & CORRECT NUMBER OF SIGNIFICANT FIGURES OBSERVED.**
- **WORK WRITTEN IN PENCIL WILL NOT BE MARKED. ONLY DRAWINGS ARE BE DONE IN PENCIL.**

**REQUIREMENTS: ONE EXAMINATION ANSWER SCRIPTS PER STUDENT**

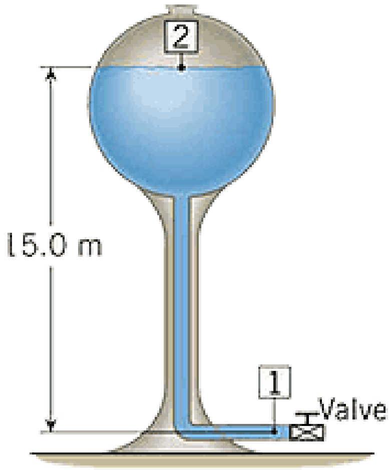
**Question 1 – Hydrodynamics [35 marks]**

1.1 State the following:

1.1.1 Archimedes' principle, and (2)

1.1.2 Bernoulli's principle. (2)

1.2 The drawing shows the water tower that is drained by a pipe that extends to the ground. Assuming that the flow is non-viscous: (6)




1.2.1 Calculate the absolute pressure at point 1 if the valve is closed, assuming that the top surface of the water at point 2 is at atmospheric pressure.

1.2.2 What is the absolute pressure at point 1 when the valve is **open** and the water is flowing? Assume the water speed at point 2 is negligible.

1.2.3 Assuming that the effective cross-sectional area of the valve opening is $2.00 \times 10^{-2}$ m$^2$, calculate the volume flow rate at point 1.

1.3 When an object is completely submerged in ethyl alcohol ($\rho$ = 806 kg.m$^{-3}$), its apparent weight measures 17.2 N. When completely submerged in water, its apparent weight measures 15.7 N. Use this information to calculate the volume of the object.

(6)

1.4 A sealed tank containing seawater to a height of 11.0 m also contains air above the water at a gauge pressure of 3.00 atm. Water flows out from the bottom through a small hole. Calculate the efflux speed of the water. (6)

1.5 What speed must an aluminium sphere with radius 2.00 mm have in castor oil at 20$^{o}$C for the viscous drag force to be one-fourth the weight of the sphere? The viscosity of castor oil at this temperature is 9.86 poise.
Density of aluminium = 2.7 × 10$^{3}$ kg.m$^{-3}$ (6)

1.6 Derive an expression for the terminal speed $v_t$ of a sphere falling in a viscous fluid in terms of the sphere's radius $r$ and density ρ and the fluid viscosity η, assuming that the flow is laminar so that Stokes' Law is valid. (7)

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**<u>Question 2 – Nuclear Physics [28 marks]</u>** **Start on a new page**

2.1 Define the following terms:

2.1.1 nuclear fusion (2)
2.1.2 nuclear fission (2)
2.1.3 mean life-time (2)

2.2 For lead $^{206}_{82}Pb$ (atomic mass = 205.974 440 u) calculate,

2.2.1 The mass defect in atomic mass units.
2.2.2 The binding energy (in MeV), and
2.2.3 The binding energy per nucleon (in MeV/nucleon). (8)

2.3 A device used in radiation therapy for cancer contains 0.50 g of cobalt $^{60}_{27}Co$ (59.933 819 u). The half-life of $^{60}_{27}Co$ is 5.27 years. Determine the activity (in Bq) of the radioactive material. (6)

2.4 In the form $^{A}_{Z}X$, identify the daughter nucleus (chemical symbol + name) that results when

2.4.1 plutonium $^{242}_{94}Pu$ undergoes α decay,
2.4.2 sodium $^{24}_{11}Na$ undergoes $\beta^{-}$ decay,
2.4.3 nitrogen $^{13}_{7}N$ undergoes $\beta^{+}$ decay, and
2.4.4 radium $^{226}_{88}Ra$ undergoes the K-capture. (8)

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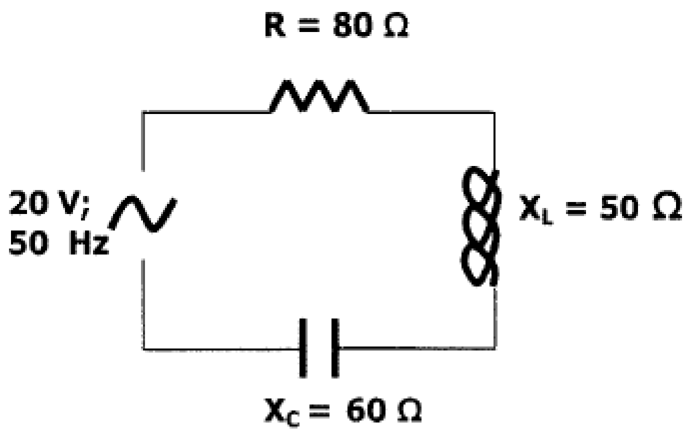
**<u>Question 3 – AC Theory [28 marks]</u>** **Start on a new page**

3.1 Explain what is meant by the term *resonance* in an ac circuit (2)

3.2 For the circuit shown below, calculate

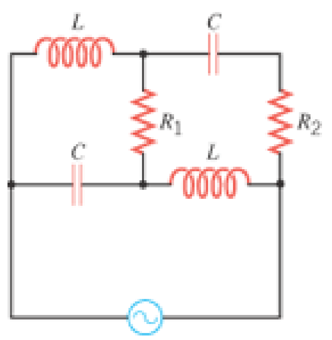



3.2.1 The current in the circuit.
3.2.2 The potential difference across each unit.
3.2.3 The power absorbed by the circuit. (9)

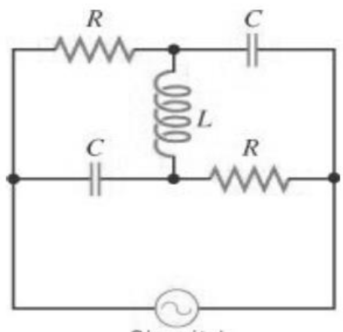
3.3 Fluorescent lights often use an inductor, called a "ballast", to limit the current through the tubes. Why is it better to use an inductor than a resistor for this purpose? (2)

3.4 The resonant frequency of a series RCL circuit is 9.3 kHz. The inductance and capacitance of the circuit are each <u>tripled</u>. What is the new resonant frequency? (5)

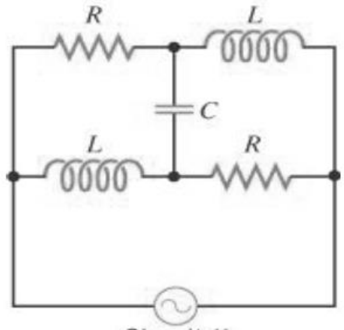
3.5 In the circuit shown below, the generator delivers four times as much current at very low frequencies as it does at very high frequencies. Find the ratio $R_2/R_1$ of the resistances. (5)



3.6 In the circuits shown, the *rms* voltage of the generator is the same. The values of resistance, capacitance and inductance are also the same. For which of the two circuits does the generator deliver more current when the frequency is very large?
Justify your answer. (5)



Circuit I



Circuit II

## Question 4 - Thermodynamics [35 marks] **Start on a new page**

4.1 State the following laws:

4.1.1 The Zeroth of Law of Thermodynamics, and (2)
4.1.2 The Third Law of Thermodynamics. (2)

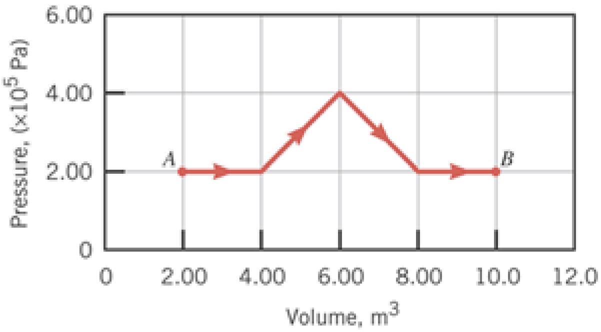
4.2 Engine *A* receives three times more input heat, produces five times more work, and rejects two times more heat than engine *B*. Find the efficiency of

4.2.1 engine *A,* and
4.2.2 engine *B*. (6)

4.3 Given an ideal gas confined in a cylinder equipped with a piston, discuss in detail, the thermodynamic process(es) that you would conduct in order to achieve the following situations:

4.3.1 Cool the gas, whilst it is doing work to its surroundings. (2)
4.3.2 Keep the internal energy of the gas constant and lower its pressure whilst it is doing work to its surroundings. (2)
4.3.3 Increase the temperature of the gas whilst the surroundings do work on the gas. (2)
4.3.4 Keep the internal energy of the gas constant and increase its pressure whilst the surroundings do work on the gas. (2)
4.3.5 Use all the heat added to the gas to increase its internal energy. (2)

4.4 A monatomic ideal gas expands from point *A* to point *B* along the path shown in the drawing.




4.4.1 Determine the work done by the gas. (4)

4.4.2 The temperature of the gas at point A is 185 K. What is its temperature at point B? (3)

4.4.3 How much heat has been added to or removed from the gas during the process? (3)

4.5 Draw a fully labelled *PV* diagram summarizing the operation of a diesel engine. (5)

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**<u>Question 5 – Heat Transfer [14 marks]</u>** **Start on a new page**

5.1 Define or state the following:

5.1.1 Convection, and (2)

5.1.2 Newton's Law of Cooling. (2)

5.2 A large hot water tank has four legs in the form of cylindrical rods which are 2.0 cm in diameter and 15 cm long. The lower ends of the legs are in good thermal contact with the floor which is at 25$^{o}$C, and their upper ends can be taken to be at the temperature of the water in the tank. The tank and the legs are well lagged so that the only heat loss is through the legs. It is found that 20 W of power are needed to maintain the tank at a temperature of 58$^{o}$C. Calculate the thermal conductivity of the material which the legs of the tank are made of. (6)

5.3 A person is standing outdoors in the shade where the temperature is 28 °C. What is the radiant energy absorbed per second by his head when covered with hair? The surface area of the hair (assumed to be flat) is 160 cm$^2$ and its emissivity is 0.85. (4)

**E N D**